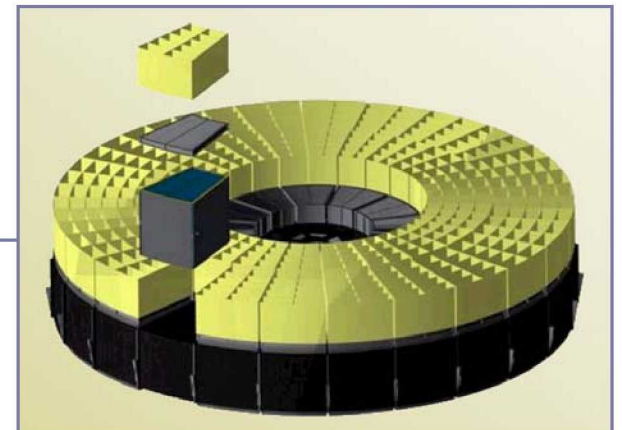


Mirror Technology for the International X-ray Observatory (iXO) Mission

Will Zhang

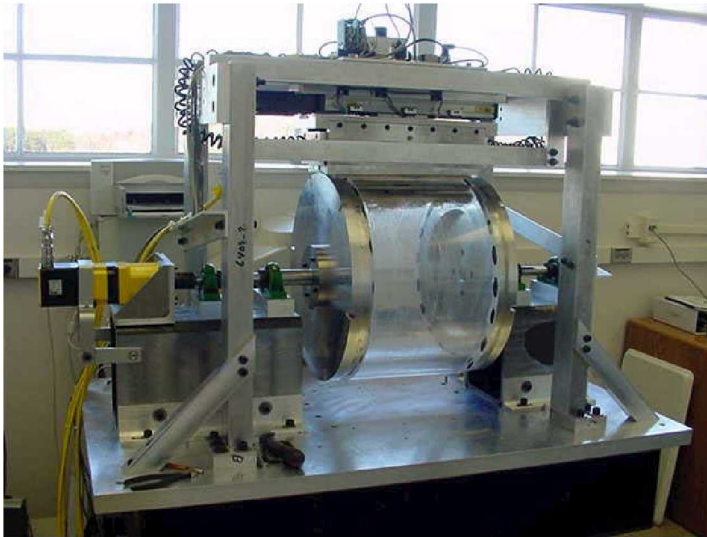
NASA Goddard Space Flight Center



Approach to Technology Development

- **Make it (mirror segment)**
 - Slumping (taking on the figure of the mandrel)
 - Cutting (getting accurate smooth edges)
 - Coating (maximizing reflectivity)
- **Measure it**
 - Suspending (letting the mirror segment be all it can be)
 - Measuring (completely capturing all parameters)
- **Hold it**
 - Suspending it and attaching it to strongback temporarily (freezing it)
 - Verifying figure and stress-free state (over-constrained, but not distorted)
- **Align it**
 - Locating it at the correct radial position
 - Orienting it in focus with other(s)
- **Bond it**
 - Permanently attaching it to housing and removing the temporary bonds
- **Do all of these with coordination and discipline (systems engineering)**
 - Every step done with the big picture in mind: structural, thermal, optical performance, and enabling the mirror segment to withstand launch and other hazards

Forming Mandrels



Full Shell Mandrels: 3 pairs completed: ~2.5" HPD (two reflection)

- 485P and 485S
- 489P and 489S
- 494P and 494S



Segment Mandrels: 2 pairs being ground

- 1480P and 1480S
- 1520P and 1520S
- Completion expected for December 2011

Mirror Segment Fabrication



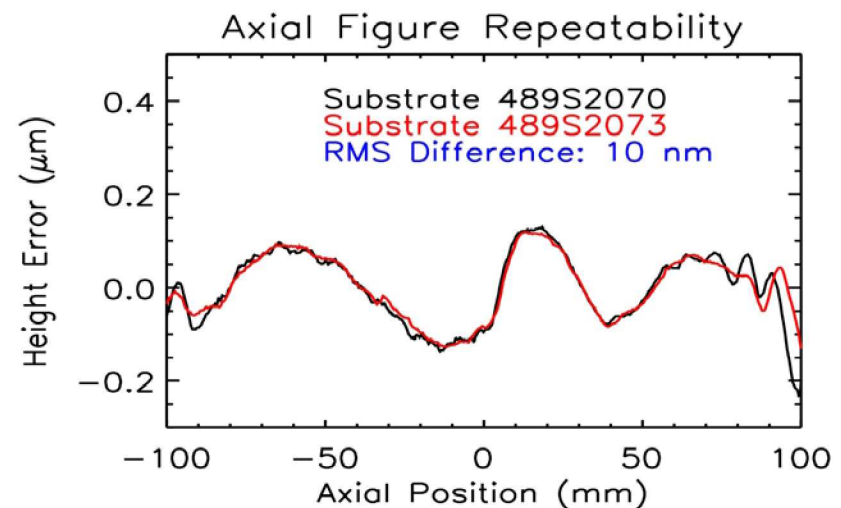
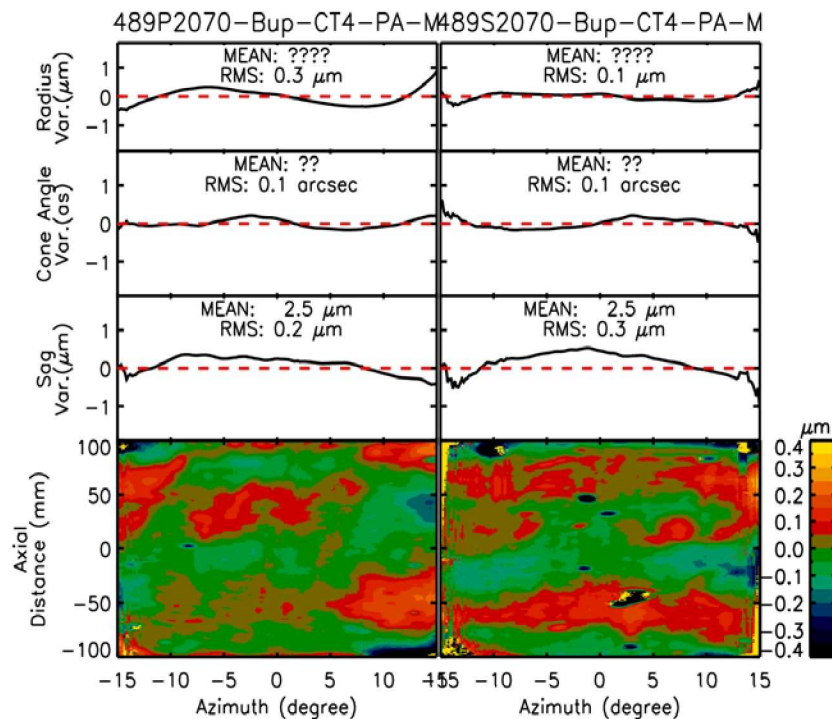
Slumping



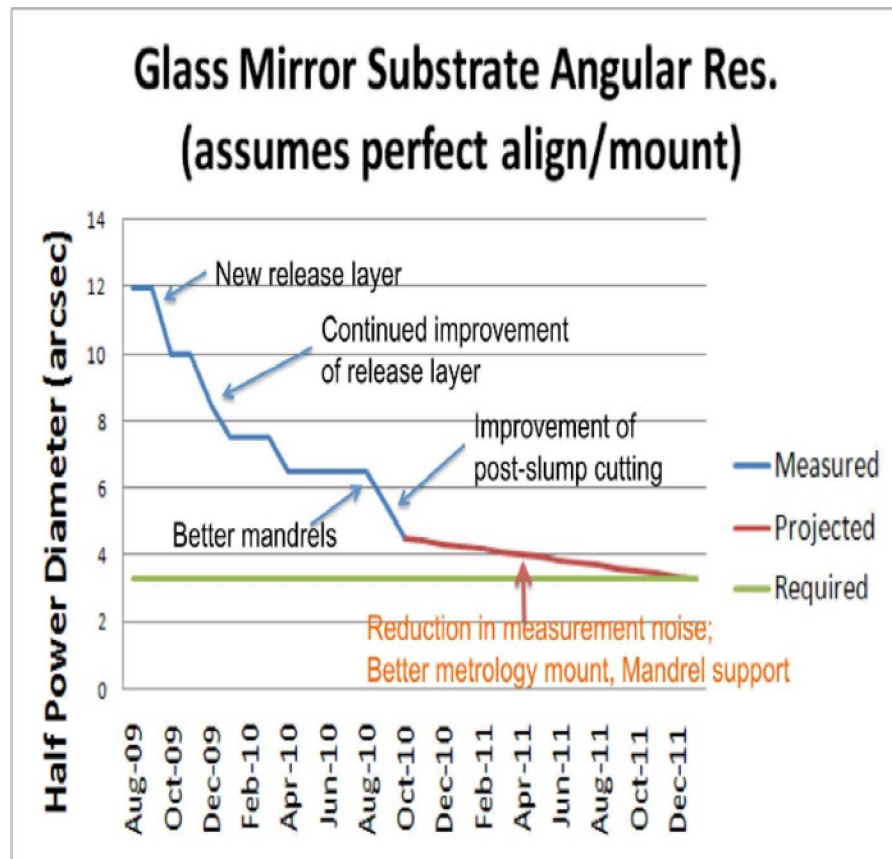
Cutting



Coating



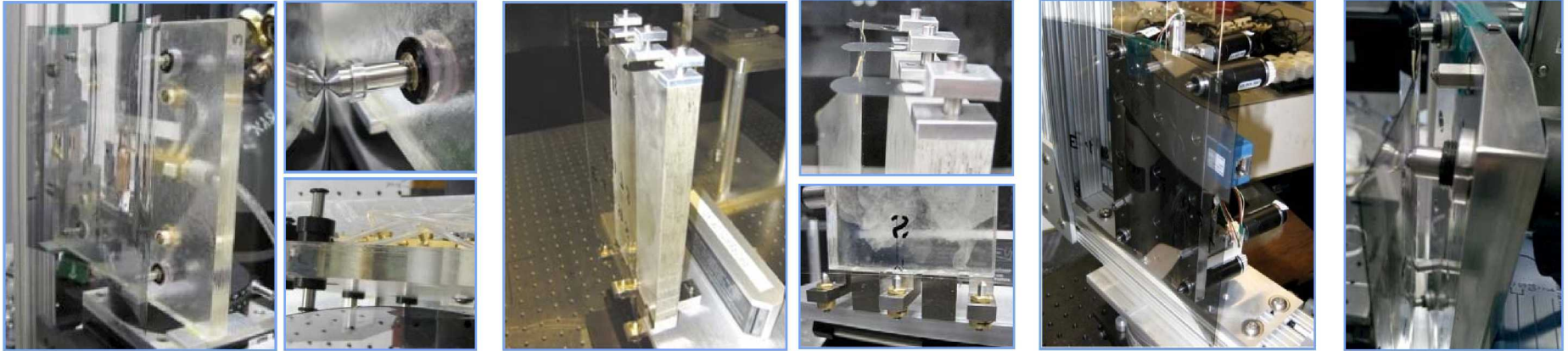
Mirror Segment Fabrication



- **Best mirror substrates: 4.5" HPD (two reflection)**
- **Typical mirror substrates: 5.5" HPD (two reflection)**
- **Work to be done to meet requirements (3.3" HPD)**
 - Better metrology, support and repeatability
 - Better thermal environment for metrology
 - Reduce distortion caused by post-slumping cutting
 - Better release layer application
 - Better mandrel support in ovens

**Objective: Demonstrate technique by December 2011;
Demonstrate manufacture consistency by December 2012**

Temporary Bonding Methods



4 Pin Air Bearing (50° mirrors)

- Hanging mirror captured on back surface by 4 pins in frictionless air bearings
- Need to transition from 50° to 30° segments in order to start with better mirrors

3 or 6 Point Edge Bond (30° mirrors)

- 1-3 flexures on top surface, 2-3 screws on bottom
- After permanent bond, de-bond of 6 temp bonds distorted mirror
- 3 point mount is being tested for less de-bond distortion

4 Point Smart Pin (30° mirrors)

- 3 suspension metrology pins steady hanging mirror (no epoxy), then bonded to 4 smart pins
- Investigating non-UV epoxy and non LDS mirror monitoring (CDS) mirror to solve thermal issues

Alignment

- Use two precision hexapods, one for primary and one for secondary
- 50 degree best: 1.1" HPD, 1.9" RMSd double reflection, nominally meeting requirements
- 30 degree best: 1.2" HPD, 1.7" RMSd double reflection, nominally meeting requirements
- Overall structural stability is being improved to achieve repeatability over periods of two days
 - Thermal stability
 - Mechanical stability

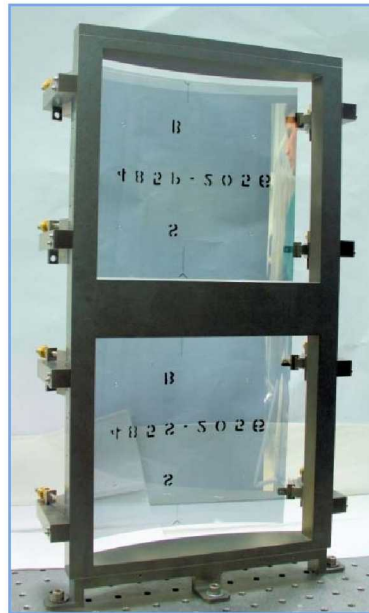


Permanent Bonding

Tab Bond

50° Permanent Bond Results

- **May trial: 10.9" RMSd**
 - 7 of 8 permanent bonds $\leq 1\mu\text{m}$
 - Issues: R19 robot, bond procedure
- **July trial: 26.7" RMSd**
 - 5 of 8 permanent bonds $\leq 1\mu\text{m}$
 - Issues: thermal, bond gap size
 - Presented results/issues at seminar
- **September trial: 10.7" RMSd**
 - 8 of 8 permanent bonds $\leq 1\mu\text{m}$
 - Issues: table stability
 - Presented results/issues at seminar

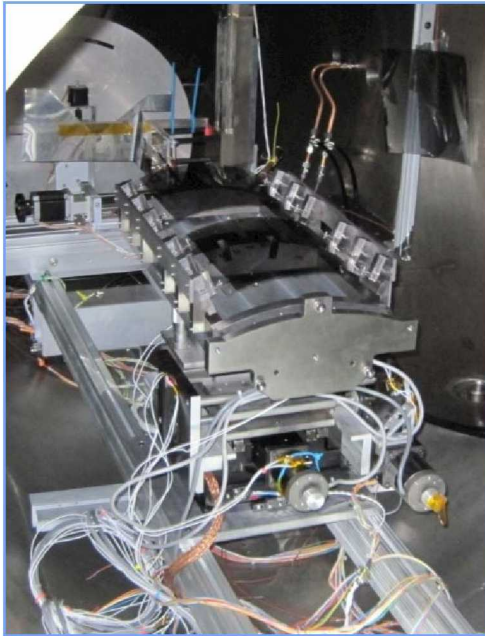


Edge Bond

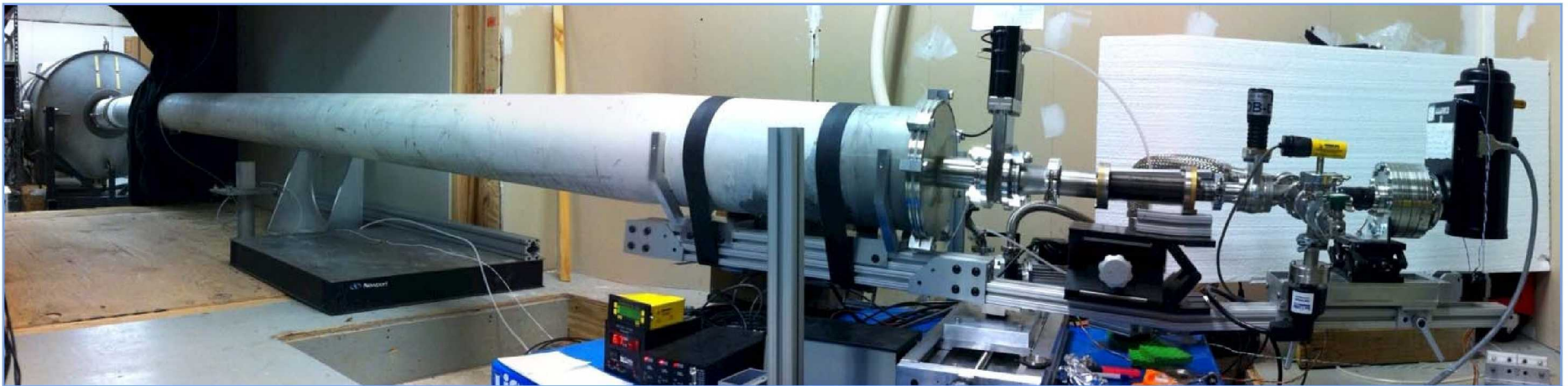
30° Permanent Bond Progress

- **Strongback GM11:**
 - Transferred mirror from top and bottom mounts on strongback (temporary) to side pin mounts on strongback (permanent) in front of interferometer with good results
- **Transferred 5 separate 30° mirrors from edge bonded strongbacks to Glass MHS**
- **6 temporary bonds per mirror**
 - Small amount of distortion noticed when permanently bonding side pins
 - Lots of distortion appeared when temporary bonds were broken
- **3 temporary bonds per mirror**
 - Lots of distortion appeared when permanently bonding side pins
 - Likely from structural instability of VAF, not bonding itself
 - More testing needed (only 1 trial complete)

X-Ray Test of Aligned and Permanently Bonded Mirror Pairs



- **Improved Area 200 X-Ray Facility**
 - Added reflective layer to roof to tighten temperature stability
 - Wired up new 4 DOF stage stack under MHS
 - Re-designed CCD detector platform to lower farther in order to accommodate mirrors in the frown orientation
- Mirror pair bonded to single MHS structure and fixed relative to each other
- Tested robustness of kinematic mounts by removing and re-inserting MHS into chamber between X-ray tests
- Found that X-ray test results were very sensitive to temperature and cycled temperature to prove hypothesis
- X-Ray result under 10 arc-seconds HPD at 4.5 keV
 - The best image using the central 34° of the mirrors was 9.7"
 - The average image was 11.3" +/- 1.0" for a span of 9 images



Milestones for 2011

- **Making mirror substrates at ~3" HPD (two reflections) level, meeting IXO requirements**
- **Repeatably and consistently temp-bond mirror segments**
 - Preserving figure
 - Stress free
- **Repeatably and consistently align and permanently bond single pairs of mirror segments in mirror housing simulators (glass or titanium)**
 - At 6 locations per mirror segment (flight-like bonds)
 - Obtain X-ray images at ~5" HPD (two reflections at 4.5 keV)
- **Co-align and permanently bond 3 pairs of mirror segments (485P/S, 489P/S, and 494P/S)**
 - At 6 locations per mirror segment (flight-like bonds)
 - Obtain X-ray images better than 10" HPD (two reflections at 4.5 keV)
- **Define requirements and plans for demonstrating TRL-6**
 - Description and definition of requirements
 - Establishment of budget and schedule for execution in subsequent years

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